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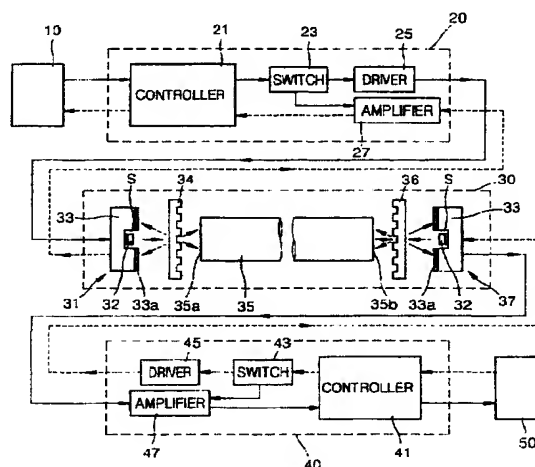
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(54) **Bidirectional signal transmission device using light**

(57) A bidirectional signal transmission device using light which adopts a photodiode-incorporated vertical cavity surface emitting laser (VCSEL) as light devices so that signal transmission and reception between facing light devices is achieved via the same channel, is provided. This bidirectional signal transmission device using light includes an optical unit (30), a first circuit unit for controlling a first light device (31), and a second circuit unit for controlling a second light device (37). The optical unit includes first and second light devices (31, 37) having a VCSEL part and a photodiode part incorporated with the VCSEL part, at least one optical fiber (35) installed between the first and second light devices (31, 37), and diffraction elements (34, 36) installed between the first light device (31) and the input port (35a) of the optical fiber and between the second light device (37) and the output port (35b) of the optical fiber (35), respectively, for selectively diffracting incident light so that light output from the optical fiber is received by the photodiode part. In this bidirectional signal transmission device using light, light emitted from an optical fiber is diffracted in an +1-th and/or -1-th order by diffraction elements, and heads for the photodiode part of the light devices, so that a received signal having a high S/N ratio can be detected. Also, the bidirectional signal transmission device using light adopts a photodiode-incorporated VCSEL manufactured as a single body in a semiconductor manufacturing process, so that a die-bonding process can be omitted.

**FIG.2**



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## Description

**[0001]** The present invention relates to a bidirectional signal transmission device using light, which is provided to convert an electrical signal into an optical signal, transmit the optical signal, and convert the transmitted optical signal back into an electrical signal, so that bidirectional signal transmission and reception between two apparatuses is achieved, and more particularly, to a bidirectional signal transmission device using light which employs a photodiode-incorporated vertical cavity surface emitting laser (VCSEL) as a light device so that an optical signal is transmitted and received via the same channel.

**[0002]** Electrical signals are typically transmitted in one direction along an electrical wire. However, in many cases, bidirectional transmission of electrical signals via one or two electrical wires is required. For example, an I<sup>2</sup>C serial bus or a universal serial bus (USB) line, which is used to facilitate data exchange between a desktop monitor and a video graphics card, requires bidirectional transmission of an electrical signal.

**[0003]** Bidirectional signal transmission using an electrical wire cannot provide transmission over a long distance due to a limit in the transmission speed, and may cause electromagnetic interference or the like. Hence, an optical signal transmission method enabling high-speed transmission without electromagnetic interference has been adopted to achieve bidirectional signal transmission.

**[0004]** Generally, for bidirectional optical signal transmission, an optical fiber serving as a transmission channel and an optical fiber serving as a reception channel are separately required, and reception and transmission of an optical signal are performed individually. However, the separate installation of a transmission channel and a reception channel complicates the hardware structure of a signal transmission device and increases the manufacturing costs thereof, so that this optical signal transmission method is difficult to put into use in spite of its numerous advantages.

**[0005]** In the prior art, a bidirectional signal transmission device designed to bidirectionally transmit an optical signal via the same channel, as shown in Figure 1, has been proposed in consideration of the above-described point.

**[0006]** Referring to Figure 1, the conventional bidirectional signal transmission device includes first and second light devices 1 and 5 for emitting light and receiving incident light, and an optical fiber 4 installed so that its input and output ports face the optical devices. The first and second light devices 1 and 5 include first and second light receiving elements 2 and 6 for receiving incident light, respectively, and first and second VCSELs 3 and 7 die-bonded to the centers of the first and second light receiving devices 2 and 6, respectively.

**[0007]** When an electrical signal from an apparatus (not shown) is received by the first optical device 1, the first VCSEL 3 emits an optical signal in response to the received electrical signal, and the optical signal is transmitted to the second light receiving element 6 via the optical fiber 4. Then, the second light receiving element 6 outputs an electrical signal that is proportional to the amount of received light, and the electrical signal is transmitted to another apparatus (not shown). Signal transmission in a direction opposite to the above-described signal transmission is achieved via the optical fiber 4 using the second VCSEL 7 and the first light receiving element 2 by the same method as the method described above.

**[0008]** The conventional bidirectional signal transmission device of Figure 1 uses the single optical fiber 4 as a transmission channel and a reception channel.

**[0009]** However, in a conventional bi-directional signal transmission device, as shown in Figure 1, light to be emitted from the output port of the optical fiber 4 is typically concentrated at the center of the optical fiber, so that the light receiving regions 2a and 6a of the light receiving elements, that are at the outside of each VCSEL, receive small amounts of light. Therefore, a received signal has a low signal-to-noise (S/N) ratio.

**[0010]** Also, when signal transmission is performed in two directions simultaneously, the light receiving elements receive not only light transmitted from the optical fiber 4 but also light which are emitted from the VCSELs on the light receiving elements and partially reflected by the input port of the optical fiber 4. Thus, there is crosstalk on a detection signal, so that, the S/N ratio of a received signal is greatly degraded.

**[0011]** Also, a VCSEL receives part of light that is emitted from a VCSEL on the opposite side and transmitted via the optical fiber 4, so that the relative intensity noise of the VCSEL is degraded. Thus, when transmission and reception of a signal are performed simultaneously in dual time at high speed, the bit error rate characteristic deteriorates.

**[0012]** Furthermore, the conventional bidirectional signal transmission device has a structure in which the VCSELs 3 and 7 are die-bonded to the light receiving elements 2 and 6, respectively, so that a yield reduction due to assembly error and bonding error may be caused during die bonding.

**[0013]** With a view to solve or reduce the above problems, it is an aim of embodiments of the present invention to provide a bidirectional signal transmission device using light, which adopts as a light device a VCSEL incorporated into a photodiode in a semiconductor manufacturing process, and is designed to increase the light receiving efficiency by installing a diffraction element for diffracting light emitted from an optical fiber and directing the diffracted light to the light receiving region of a light receiving element, between a light device and the input/output port of the optical fiber.

**[0014]** According to a first aspect of the present invention is achieved by a bidirectional signal transmission device using light including: an optical unit including at least one of first and second light devices having a vertical cavity

surface emitting laser (VCSEL) unit for emitting light in the direction semiconductor material layers are stacked and a photodiode part incorporated with the VCSEL part for receiving incident light, at least one optical fiber installed between facing first and second light devices for transmitting an optical signal, and diffraction elements installed between the first light device and one input/output port of the optical fiber and between the second light device and the other input/output port of the optical fiber, respectively, for selectively diffracting incident light so that light output from the optical fiber is received by the photodiode part; a first circuit unit for controlling the first light device so that an electrical signal from a first apparatus is converted into an optical signal, and that an optical signal transmitted via the optical fiber is converted into an electrical signal and then transmitted to the first apparatus; and a second circuit unit for controlling the second light device so that an electrical signal from a second apparatus is converted into an optical signal, and that an optical signal transmitted via the optical fiber is converted into an electrical signal and then transmitted to the second apparatus, wherein signal transmission and reception between the facing first and second light devices are performed via the same channel.

**[0015]** The diffraction element is a diffraction grating or hologram optical element for diffracting incident light in a +1-th and/or -1-th order.

**[0016]** Preferably, the diffraction pattern of the diffraction element has an angular or blazed cross-section.

**[0017]** Preferably, the interval between the diffraction element and the input/output port of the optical fiber is smaller than the interval between the diffraction element and the first/second light devices.

**[0018]** The corresponding first and second light devices preferably emit perpendicular polarized light beams, and the diffraction element is a polarization diffraction element designed so that polarized light incident from the VCSEL part is transmitted straight and received by the optical fiber, and that polarized light incident from the optical fiber is diffracted in a +1-th and/or -1-th order and headed for the photodiode part.

**[0019]** Preferably, the polarization diffraction element is a refractivity change diffraction element obtained by forming a proton exchange region and a dielectric film on the position of the diffraction pattern of a plate made of a birefringence material.

**[0020]** Here, the optic axis of the polarization diffraction element is preferably approximately perpendicular to the direction of linear polarization of light emitted from a VCSEL part that faces the polarization diffraction element.

**[0021]** The optical unit may further comprise a lens installed between a VCSEL part and a diffraction element or between the diffraction element and the input/output port of an optical fiber, for coupling light from a VCSEL part to the optical fiber.

**[0022]** The optical unit may be single-modularized, so that it is electrically separated/connected from/to the first and second apparatuses.

**[0023]** The optical unit and at least some components of the first and second circuit units are preferably single modularized.

**[0024]** Each of the first and second circuit units preferably includes: a driver for driving a VCSEL part; and an amplifier for amplifying a current signal output from the photodiode part.

**[0025]** Preferably, each of the first and second circuit units further includes a controller installed between an apparatus and the amplifier and the driver, for converting an electrical signal from the apparatus into a signal that is suitable for controlling the driver, and converting a signal from the amplifier into a signal suitable for the apparatus.

**[0026]** The controller may comprise: an encoder for encoding an electrical signal from an apparatus into an appropriate signal; a driver control core for converting the encoded signal into a signal that is suitable for controlling the driver, and applying the converted signal to the driver; and a decoder for decoding a signal from the amplifier into a signal that is suitable for the apparatus.

**[0027]** The controller may further comprise a multiplexer between the encoder and the driver control core.

**[0028]** It is also preferable that the first and/or second circuit unit further includes a switch installed between the controller and the driver and amplifier, for selectively switching on and off the driver and/or the amplifier.

**[0029]** For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which:

Figure 1 is a schematic view of an example of a conventional bidirectional signal transmission device;

Figure 2 is a schematic view illustrating the entire structure of a bidirectional signal transmission device using light adopting an optical unit according to an embodiment of the present invention;

Figures 3 and 4 are schematic views of the shapes of the cross-section of the diffraction pattern of a diffraction element according to other embodiments of the present invention;

Figure 5 schematically shows another embodiment of an optical unit according to the present invention;

Figure 6 is a view illustrating the polarized light diffracting element of Figure 5;

Figures 7 and 8 are schematic views of other embodiments of the optical unit of Figures 2 and 5;

Figures 9 and 10 are block diagrams of embodiments of a controller according to the present invention; and

Figure 11 is a block diagram of another embodiment of first and second circuit units according to the present invention.

**[0030]** Figure 2 is a schematic view of a bidirectional signal transmission device using light which adopts an optical unit according to an embodiment of the present invention. Referring to Figure 2, the bidirectional signal transmission device using light according to the present invention includes an optical unit 30 and first and second circuit units 20 and 40. The optical unit 30 includes first and second light devices 31 and 37 for converting an electrical signal into an optical signal, transmitting the optical signal, and converting the transmitted optical signal back into an electrical signal, so that it can transmit a signal in two directions. The first circuit unit 20 drives the first light device 31 in response to an electrical signal output from a first apparatus 10, and converts an electrical signal output from the first light device 31 into a signal that is suitable for the first apparatus 10. The second circuit unit 40 drives the second light device 37 in response to an electrical signal output from a second apparatus 50, and converts an electrical signal output from the second light device 37 into a signal that is suitable for the second apparatus 50.

**[0031]** The optical unit 30 includes the first and second light devices 31 and 37, an optical fiber 35, and first and second diffraction elements 34 and 36. The first and second light devices 31 and 37 convert an electrical signal into an optical signal and converts the optical signal back into an electrical signal. The optical fiber 35 is installed between the first and second light devices 31 and 37, and transmits incident light. The first and second diffraction elements 34 and 36 are installed between the input port 35a of the optical fiber 35 and the first light device 31 and between the output port 35b of the optical fiber 35 and the second light device 37, respectively.

**[0032]** Preferably, photodiode-incorporated VCSELs are adopted as the first and second light devices 31 and 37, so that a signal can be transmitted and received via a single channel. The photodiode-incorporated VCSEL is made up of a VCSEL part 32 for emitting light in the direction in which the semiconductor material layers are stacked, and a photodiode part 33 incorporated with the VCSEL part 32 for receiving light that is incident upon the peripheral portions of the VCSEL part 32.

**[0033]** The photodiode-incorporated VCSEL is fabricated in a single body by a semiconductor manufacturing process. For example, the photodiode-incorporated VCSEL is manufactured by forming the basic semiconductor stacked structure of a VCSEL on a semiconductor substrate, etching the outskirts of the VCSEL part 32 to electrically isolate the VCSEL part 32 from the photodiode part 33, forming the semiconductor structure of the photodiode part 33 by etching and/or stacking some layers of the photodiode part 33, and forming electrode patterns on the VCSEL part 32 and the photodiode part 33. Figure 2 shows an example in which the photodiode part 33 protrudes more than the VCSEL part 32, and a space S for electrical insulation is formed between the VCSEL part 32 and the photodiode part 33. Here, the space S can be coated with an insulating material. The semiconductor stacked structure of the VCSEL part 32 and the photodiode part 33 is well known, so it will not be shown or described in detail.

**[0034]** When the described photodiode-incorporated VCSEL is used as the first and second light devices 31 and 37, a special assembly process such as die bonding is not needed. Therefore, the use of the described photodiode-incorporated VCSEL prevents yield reduction due to assembly errors and bonding errors during die bonding, which is a problem that occurs in a conventional bidirectional signal transmission device.

**[0035]** The optical fiber 35 transmits light received from the first and second light devices 31 and 37. It is preferable that the optical fiber 35 is a plastic optical fiber which costs less than a glass optical fiber and is easier for optical coupling than the glass optical fiber because of the large diameter of the plastic optical fiber. The use of the plastic optical fiber as the optical fiber 35 can reduce damage to the optical fiber 35 due to external impacts.

**[0036]** The first and second diffraction elements 34 and 36 are installed between the input port 35a of the optical fiber 35 and the first light device 31 and between the output port 35b of the optical fiber 35 and the second light device 37, respectively. Here, the first and second diffraction elements 34 and 36 are diffraction gratings or hologram optical elements for diffracting incident light in a +1-th and/or -1th order. The first and second diffraction elements 34 and 36 couple as much light output from the optical fiber 35 as possible to the receiving region 33a of the photodiode part 33 at the outside of the VCSEL part 32, thereby increasing the reception efficiency of light transmitted via the optical fiber 35. Thus, a received optical signal having a high S/N ratio can be detected.

**[0037]** The intensity of light output from the optical fiber 35 is concentrated along the optical axis of the optical fiber 35, so that the light approximately has a Gaussian intensity distribution. Accordingly, when light output from the optical fiber 35 is diffracted in a +1-th and/or -1-th order as described above, most of the light is received by the light receiving region 33a of the photodiode part 33 on the outside of the VCSEL part 32. Hence, the bidirectional signal transmission

device using light according to the present invention does not have the problems of a conventional bidirectional signal transmission device, such as a degradation of the light reception efficiency due to most light heading for a VCSEL located at the center of a light device, or a degradation in the relative intensity noise of the VCSEL. The first and second diffraction elements 34 and 36 diffract not only light output from the input and output ports 35a and 35b of the optical fiber 35 but also light which is emitted from the VCSEL part 32 and heads for the input and output ports 35a and 36b of the optical fiber 35, in a +1-th and/or -1th order. Hence, it is preferable that the first and second diffraction elements 34 and 36 are closer to the input and output ports 35a and 35b of the optical fiber 35 than to the first and second light devices 31 and 37, respectively. In this case, light emitted from the VCSEL part 32 is diffracted in a +1-th and/or -1th order by the first and second diffraction elements 34 and 36. However, since the first and second diffraction elements 34 and 36 are close to the input and output ports 35a and 35b of the optical fiber 35, a sufficient amount of light can be input to the optical fiber 35. Also, since the first and second diffraction elements 34 and 36 are separated from the first and second light devices 31 and 37 at relatively sufficient intervals, most of the light diffracted in a +1-th and/or -1th order can be received by the light receiving region 33a of the photodiode part 33.

[0038] Here, the diffraction of incident light only in a +1-th and/or -1th order, not in zero-th order, by the first and second diffraction elements 34 and 36 is achieved by removing zero-th light by controlling the pattern depth of a diffraction pattern, for example, the grating depth of a diffraction grating, to have a phase difference of one half wavelength.

[0039] For example, the duty ratio as shown in Figure 3 is 0.5, the diffraction angle ( $\theta$ ) of a diffraction grating, the diffraction pattern (the grating pattern) of which has an angular cross-section, is expressed in Equation 1:

$$\theta = \text{Arc sin}(k\lambda/T) \quad (1)$$

wherein  $\lambda$  denotes the wavelength of incident light,  $T$  denotes the grating period, and  $k$  denotes the diffraction order such as 0,  $\pm 1$ ,  $\pm 2$ ,  $\pm 3$ , .... A zero-th order diffracted light efficiency ( $\eta_0$ ) and  $\pm 1$ -th order diffracted light efficiency ( $\eta_{\pm 1}$ ) are expressed in Equation 2:

$$\begin{aligned} \eta_0 &= \cos^2 \phi \\ \eta_{\pm 1} &= 4 \sin^2 \phi / \pi^2 \end{aligned} \quad (2)$$

wherein  $\phi$  is  $\pi/(\lambda(n-1)d)$  (where  $d$  indicates the grating depth, and  $n$  indicates the refractivity).

[0040] Accordingly, when the first and second diffraction elements 34 and 36 according to the present invention are angular diffraction gratings having a duty ratio of 0.5, as shown in Figure 3, and a grating depth ( $d$ ) and a refractivity ( $n$ ) that allow the zero-th order diffraction efficiency to be zero with respect to the wavelength ( $\lambda$ ) of light emitted from the first and second light devices 31 and 37, the maximum optical efficiency, the sum of light diffracted in +1-th and -1-th orders by the first and second diffraction elements 34 and 36, is about 82%, and light is rarely diffracted in the zero-th order.

[0041] Also, the first and second diffraction elements 34 and 36 according to the present invention can be blazed diffraction gratings, the diffraction pattern of which has a blazed cross-section, as shown in Figure 4, in order to increase the diffraction efficiency. If the blazed diffraction grating diffracts incident light in a +1-th order, and is blazed in 8 steps, the efficiency of +1-th order diffracted light is about 95%.

[0042] When the blazed diffraction gratings are adopted as the first and second diffraction elements 34 and 36, they provide a high efficiency of diffracting incident light in the 1-th order, compared to angular diffraction gratings, so that a high S/N ratio can be obtained. This merit is also guaranteed when angular or blazed hologram elements, the diffracting pattern of which has an angular or blazed cross-section, are adopted as the first and second diffracting elements 34 and 36. Figure 2 shows an example in which diffraction gratings or hologram elements, the diffracting pattern of which has an angular cross-section, are adopted as the first and second diffraction elements 34 and 36.

[0043] The optical unit 30 according to the present invention can include first and second polarization diffraction elements 134 and 136 instead of the first and second diffraction elements 34 and 36, as shown in Figure 5. Here, the first and second light devices 31 and 37 are disposed to linearly emit polarized light beams in approximately perpendicular directions. A VCSEL usually emits approximately linearly-polarized light. Accordingly, when the first and second light devices 31 and 37 are arranged so that the directions of linear polarization of light emitted from the VCSEL part 32 cross each other at right angles, they can emit polarized light in perpendicular directions.

[0044] The first and second polarization diffraction elements 134 and 136 can be refractivity change diffracting elements, as shown in Figure 6. A refractivity change diffracting element is obtained by forming a proton exchange layer 137 on a birefringence plate 135 made of a birefringence material such as  $\text{LiNbO}_3$ , in a diffraction grating or hologram

diffraction pattern, and forming a dielectric film 139 on the proton exchange layer 137.

**[0045]** For example, the refractivity change diffracting element does not change the refractive index of ordinary light and changes the refractive index of extraordinary light to generate +1-th and -1-th order diffracted light.

That is, ordinary light travels straight due to a refractive index corresponding to the difference in the refractive index between the proton exchange layer 137 and the dielectric film 139. This is because little refractive index difference is experienced by ordinary light between the birefringence plate 135 and the proton exchange layer 137 and the dielectric film 139. Conversely, extraordinary light undergoes a refractive index corresponding to the sum of the refractive index of the proton exchange layer 137 and that of the dielectric film 139, so that it is diffracted in +1-th and -1-th orders. This is because a big refractive index difference is experienced by extraordinary light between the birefringence plate 135 and the proton exchange layer 137 and the dielectric film 139.

**[0046]** Here, ordinary light corresponds to the case where the direction of linear polarization of incident light is perpendicular to the optic axis of the birefringence plate 135, and extraordinary light corresponds to the case where the direction of linear polarization of incident light is parallel to the optic axis of the birefringence plate 135.

**[0047]** Accordingly, the first and second polarization diffraction elements 134 and 136 are disposed so that the optic axis of the birefringence plate 135 of the first polarization diffraction element 134 is perpendicular to that of the counterpart of the second polarized light diffraction element 136, and simultaneously so that the direction of the optic axis of the birefringence plate 135 is perpendicular to the direction of linear polarization of light emitted from the first and second light devices 31 and 37 which face each other.

**[0048]** Thus, the first polarization diffraction element 134 diffracts light, which has been linearly polarized in a first direction and emitted from the VCSEL part 32 of the first light device 31, in the zero-th order, and directs the diffracted light toward the input/output ports 35a/35b of the optical fiber 35. Also, the first polarization diffraction element 134 diffracts light, which has been linearly polarized in a second direction that is perpendicular to the first direction, and emitted from the second light device 37 via the optical fiber 35, in the +1-th and/or -1-th order, and directs the diffracted light toward the photodiode part 33 of the first light device 31.

**[0049]** Similarly, the second polarization diffraction element 136 diffracts light, which has been linearly polarized in the second direction and emitted from the VCSEL part 32 of the second light device 37, in the zero-th order, and directs the diffracted light toward the input/output ports 35a/35b of the optical fiber 35. Also, the second polarization diffraction element 136 diffracts light, which has been linearly polarized in the first direction and emitted from the first light device 31 via the optical fiber 35, in the +1-th and/or -1-th order, and directs the diffracted light toward the photodiode part 33 of the second light device 37.

**[0050]** Accordingly, light output from the input/output port 35a/35b of the optical fiber 35 is mostly diffracted in the +1-th and/or -1-th order by the first/second polarization diffraction element 134/136 and received by the photodiode part 33 of the first/second light device 31/37.

**[0051]** Hence, if the optical unit 30 having the above-described first and second polarization diffraction elements 134 and 136 is adopted, when digital communications takes place in dual time at high speed, light output from a VCSEL part can be prevented from being coupled to the opposite VCSEL part. The use of the optical unit 30 having such a structure prevents a deterioration in the relative intensity noise of a VCSEL part caused by the coupling of light from the opposite VCSEL part to the VCSEL part in a conventional structure, and also prevents a consequential degradation of the bit error rate of a signal. Furthermore, light emitted from the VCSEL part of a light device is prevented from being partly reflected by the input/output port of the optical fiber 35, and heading for the photodiode part. Therefore, crosstalk of a detection signal caused by partial deflection of light by the input/output port of an optical fiber is not generated.

**[0052]** The optical unit 30 according to the present invention shown in Figures 2 and 5 can further include lenses 238 and 239 for focusing incident light, between the first diffraction element 34 or 134 and the input port 35a of the optical fiber 35 and between the second diffraction element 36 or 136 and the output port 35b of the optical fiber 35, respectively, as shown in Figure 7, in order to increase the efficiency of coupling light emitted from the VCSEL part 32 to the optical fiber 35. The lenses 238 and 239 can be installed between the first light device 31 and the first diffraction element 34 and between the second light device 37 and the second diffraction element 36, respectively, as shown in Figure 8.

**[0053]** Referring back to Figure 2, the first and second circuit units 20 and 40 include first and second drivers 25 and 45 for driving the VCSEL part 32 of the first and second light devices 31 and 37, and first and second amplifiers 27 and 47 for amplifying a current signal output from the photodiode part 33 of the first and second light devices 31 and 37, respectively.

**[0054]** Preferably, the first and second circuit units 20 and 40 further include a first controller 21 installed between the first amplifier 27 and the first driver 25 and the first apparatus 10, and a second controller 41 installed between the second amplifier 47 and the second driver 45 and the second apparatus 50, respectively. Also, preferably, the first and second circuit units 20 and 40 further include a first switch 23 installed between the first driver 25 and the first amplifier 27 and the first controller 21, and a second switch 43 installed between the second driver 45 and the second amplifier 47 and the second controller 41, respectively.

[0055] The first and second controllers 21 and 41 convert electrical signals received from the first and second apparatuses 10 and 50 into signals having formats that are suitable for controlling the first and second drivers 25 and 45, respectively, and also convert signals output from the first and second amplifiers 27 and 47 into signals having formats that are suitable for the first and second apparatuses 10 and 50, respectively.

[0056] Each of the first and second controllers 21 and 41 includes an encoder 123, a driver control core 125 and a decoder 127, as shown in Figure 9. The encoder 123 encodes an electrical signal from each of the first and second apparatuses 10 and 50 into a signal having a suitable format. The driver control core 125 converts a signal encoded by the encoder 123 into a signal having a format that is suitable for controlling each of the first and second drivers 25 and 45, and applies the converted signal to each of the first and second drivers 25 and 45. The decoder 127 decodes a signal received from each of the first and second amplifiers 27 and 47 into a signal having a format that is suitable for each of the first and second apparatuses 10 and 50. Preferably, each of the first and second controllers 21 and 41 further includes a multiplexer (MUX) 129 between the encoder 123 and the driver control core 125, as shown in Figure 10. The MUX 129 feeds a signal detected by the photodiode part 37 back to the driver control core 125 or the driver 25 (45), and controls the VCSEL part 32 according to the detected signal.

[0057] Referring back to Figure 2, the first and second switches 23 and 43 operate mutually correspondingly under the control of the first and second controllers 21 and 41, and selectively switch on and off the drivers 25 and 45 and the amplifiers 27 and 47, respectively.

[0058] The signal transmission device using light according to the present invention having the first and second switches 23 and 43 is adopted between the first and second apparatuses 10 and 50, so that the first and second apparatuses 10 and 50 can exchange appropriate signals with each other.

[0059] That is, when a system, which is designed so that the first and second apparatuses 10 and 50 can alternately exchange signals as needed while simultaneously transmitting and receiving signals in two directions, adopts as the signal transmission device using light according to the present invention, even when the S/N ratio of a received signal is severely degraded, or even upon a mode where one apparatus sends a signal and then the other apparatus sends a responding signal, the first and second switches 23 and 43 operate mutually correspondingly under the control of the first and second controllers 21 and 41, respectively. Thus, the first and second apparatuses 10 and 50 can exchange signals in turns.

[0060] Also, when a system, which is designed so that the first and second apparatuses 10 and 50 transmit and receive signals bidirectionally, adopts the signal transmission device using light according to the present invention, the first and second switches 23 and 43 operate mutually correspondingly under the control of the controllers 21 and 41, respectively, even when the S/N ratio of a signal is degraded. Consequently, the S/N ratio of a signal increases, resulting in a reduction in the data transmission error rate.

[0061] For example, when a signal, which is transmitted from one of the first and second light devices 31 and 37 via the optical fiber 35 and received by the photodiode part 33, is severely degraded by light from the VCSEL part 32 of the other light device being reflected by a light device such as the diffraction elements 34, 36, 134 and 136 and/or the lenses 138 and 139, or by the input/output port 35a/35b of the optical fiber 35, and received by the photodiode part 33 of the other light device, the first and second switches 23 and 43 are operated to alternately switch on and off the first and second drivers 25 and 45 and the second and first amplifiers 47 and 27 under the control of the first and second controllers 21 and 41, respectively. Thus, a signal is transmitted in turns between the first and second apparatuses 10 and 50. When the signal transmission is performed in turns, as described above, the speed of signal transmission between the first and second apparatuses 10 and 50 decreases, but a signal can be received at a high S/N ratio. This leads to a reduction in the error rate of data transmission.

[0062] When a system, which is designed so that the first and second apparatuses 10 and 50 transmit signals in one direction, adopts the signal transmission device using light according to the present invention, one switch transmits a driving signal to a driver and simultaneously keeps an amplifier in an off state, and the other switch switches off a driver and simultaneously keeps an amplifier in an on state. This enables transmission of a signal in one direction.

[0063] When a system, which is designed so that the first and second apparatuses 10 and 50 exchange a signal with each other in turns, adopts the signal transmission device using light according to the present invention, the first and second switches 23 and 43 alternately switch on and off the first and second drivers 25 and 45 and the second and first amplifiers 47 and 27. Thus, signal exchange between apparatuses is performed in turns.

[0064] When a system, which is designed so that the first and second apparatuses 10 and 50 necessarily exchange signals with each other in two directions at the same time, adopts the signal transmission device using light according to the present invention, the first and second switches 23 and 43 switch on the first and second drivers 25 and 45 and the first and second amplifiers 27 and 47, respectively, and are maintained in on states. Hence, signals can be transmitted and received in two directions at the same time.

[0065] Of course, in the case of a system designed so that the first and second apparatuses 10 and 50 necessarily exchange signals with each other at the same time, the signal transmission device using light according to the present invention can adopt first and second circuit units 20 and 40 each having no switches, as shown in Figure 11.

**[0066]** In the signal transmission device using light according to the present invention having such a structure, it is preferable that an optical unit 30 is single-modularized. When the optical unit 30 is single-modularized, the first and second apparatuses 10 and 50 may be electrically separated/connected from/to the optical unit 30.

**[0067]** A conventional signal transmission device has a structure in which apparatuses are connected to each other by attachment of a connector on which a light device is installed to a connector on which an optical fiber is installed, so that the optical alignment error between the light device and the optical fiber is generated by repetition of attachment and detachment between the two connectors. This causes data error and a change in the amplitude of an optical signal. In contrast to the conventional signal transmission device as described above, the signal transmission device according to the present invention does not have these problems, thus guaranteeing reliability.

**[0068]** When the signal transmission device according to the present invention having the single-modularized optical unit 30 described above is applied to typical apparatuses designed so that signal transmission is performed by electrical connection, even when the first and second circuit units 20 and 40 are diversely combined between the optical unit 30 and the first apparatus 10 and between the optical unit 30 and the second apparatus 50, as described later, there is no need to change the port structure of an apparatus. Hence, a signal transmission device according to the present invention adopting the single-modularized optical unit 30 is compatible for general-purpose apparatuses.

**[0069]** The first and second circuit units 20 and 40 can be single-modularized with the optical unit 30. That is, the first circuit unit 20, and the first light device 31, the diffraction element and one end of the optical fiber 35 in the optical unit 30 can be installed at a first connector (not shown) for enabling electrical connection to the first apparatus 10, and the second circuit unit 40, and the second light device 37, the diffraction element and the other end of the optical fiber 35 in the optical unit 30 can be installed at a second connector (not shown) for enabling electrical connection to the second apparatus 50. In this case, when the first and second connectors are fit into the first and second apparatuses 10 and 50, respectively, the signal transmission device using light according to the present invention is electrically coupled to the first and second apparatuses 10 and 50, and converts electrical signals from the first and second apparatuses 10 and 50 into optical signals, transmit the optical signals via the optical fiber 35, convert the optical signals back into electrical signals, and transmit the electrical signals to the second and first apparatuses 50 and 10, respectively.

**[0070]** In each of the first and second circuit units 20 and 40, at least one among some component elements, for example, a driver and an amplifier, is modularized with the optical unit 30, and the rest can be installed in the first and second apparatuses 10 and 50.

**[0071]** The whole component elements of the first and second circuit units 20 and 40 can be installed in the first and second apparatuses 10 and 50, respectively. In this case, the first and second apparatuses 10 and 50 are electrically connected to the optical unit 30, such that a driving signal output from the driver of a circuit unit installed in the first and/or second apparatuses 10 and/or 50 is transmitted to the optical unit 30, and an electrical signal output from the optical unit 30 is applied to the amplifier of the circuit unit installed in the first and/or second apparatuses 10 and/or 50.

**[0072]** Here, only some components of the optical unit 30 are modularized, and the rest can be installed in the first and/or second apparatuses 10 and/or 50. For example, the first and second light devices 31 and 37 are installed in the first and second apparatuses 10 and 50, respectively, together with the first and second circuit units 20 and 40, while only the diffraction elements 34 and 36 (or 134 and 136) and the optical fiber 35 can be modularized. In this case, the optical unit 30 modularized separately from the first and second apparatuses 10 and 50 has a port structure for optical connection. Alternatively, the first light device 31 and the first diffraction element 34 or 134 are installed in only the first apparatus 10, while the remaining components can be modularized. In this case, the modularized optical unit 30 and the first apparatus 10 have port structures for optical connection, and is electrically connected to the second apparatus 50.

Here, the first circuit unit 20, the first light device 31 and a diffraction element are installed in the first apparatus 10, while the second circuit unit 40, the second light device 37 and a diffraction element are installed in the second apparatus 50. In this case, the first and second apparatuses 10 and 50 have port structures by which they can be optically connected to the input/output port 35a/35b of the optical fiber 35.

**[0073]** In the above, the case in which a signal transmission device using light according to the present invention includes a pair of first and second light devices and a single optical fiber installed to face them so that signal transmission and reception via a single channel can be achieved, has been described as an example. The signal transmission device using light according to the present invention can be simply converted to a multi-channel signal transmission device by setting the first and second light devices in array and installing an optical fiber between facing first and second light devices. Thus, a multi-channel signal transmission device using light according to the present invention will not be shown and described in detail since it can be sufficiently inferred from the structure of a single-channel signal transmission device.

**[0074]** The signal transmission device using light according to the present invention as described above includes a diffraction element between the input/output port of an optical fiber and a light device, so that light emitted from the optical fiber is diffracted in a +1-th and/or -1-th order and heads for the photodiode part of the light device. Thus, a

received optical signal having a high S/N ratio can be detected.

[0075] Also, since light emitted from the optical fiber is diffracted in a +1-th and/or -1-th order and headed for the photodiode part of the light device, there is no degradation in the relative intensity noise of a VCSEL caused by a conventional structure in which part of light, which is emitted from the opposite VCSEL and transmitted via an optical fiber, is incident upon the VCSEL. Accordingly, even when signal transmission and reception are performed simultaneously in dual time, an excellent signal bit error rate can be obtained.

[0076] Also, since a VCSEL incorporated into a photodiode in a semiconductor manufacturing process is adopted as the light device, a die-bonding process can be omitted. Thus, assembly errors caused upon die bonding, and a yield reduction due to bonding error in the conventional structure are not generated.

[0077] Furthermore, when a polarization diffraction element is adopted as the diffraction element, light emitted from the VCSEL part of the light device can be prevented from being partly reflected by the input/output port of the optical fiber and heading for the photodiode part. Thus, crosstalk of a detection signal caused by light partly reflected by the input/output port of an optical fiber is not generated.

[0078] The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0079] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0080] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0081] The invention is not restricted to the details of the foregoing embodiment(s). The invention extend to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

## Claims

1. A bidirectional signal transmission device using light designed so that signal transmission and reception between facing light devices are accomplished via the same channel, the device **characterized by** comprising:

an optical unit (30) including first and second light devices (31, 37) having a vertical cavity surface emitting laser (VCSEL) unit for emitting light in the direction semiconductor material layers are stacked and a photodiode part (33) incorporated with the VCSEL part (32) for receiving incident light, at least one optical fiber (35) installed between facing first and second light devices (31, 37) for transmitting an optical signal, and diffraction elements (34, 36) installed between the first light device (31) and the input port (35a) of the optical fiber (35) and between the second light device (37) and the output port (35b) of the optical fiber (35), respectively, for selectively diffracting incident light so that light output from the optical fiber (35) is received by the photodiode part (33);

a first circuit unit (20) for controlling the first light device (31) so that an electrical signal from a first apparatus (10) is converted into an optical signal, and that an optical signal transmitted via the optical fiber (35) is converted into an electrical signal and then transmitted to the first apparatus (10); and

a second circuit unit (40) for controlling the second light device (37) so that an electrical signal from a second apparatus (50) is converted into an optical signal, and that an optical signal transmitted via the optical fiber (35) is converted into an electrical signal and then transmitted to the second apparatus (50),

wherein signal transmission and reception between the facing first and second light devices (31, 37) are performed via the same channel.

2. The bidirectional signal transmission device using light of claim 1, wherein the diffraction element (34, 36) is a diffraction grating or hologram optical element for diffracting incident light in a +1-th and/or -1-th order.
3. The bidirectional signal transmission device using light of claim 2, wherein the diffraction pattern of the diffraction element (34, 36) has an angular or blazed cross-section.

4. The bidirectional signal transmission device using light of claim 2 or 3, wherein the interval between the diffraction element (34, 36) and the input/output port (36a, 35b) of the optical fiber (35) is smaller than the interval between the diffraction element (34, 36) and the first/second light devices (31, 37).
5. The bidirectional signal transmission device using light of claim 1, wherein the corresponding first and second light devices (31, 37) emit perpendicular polarized light beams, and the diffraction element (34, 36) is a polarization diffraction element designed so that polarized light incident from the VCSEL part is transmitted straight and received by the optical fiber, and that polarized light incident from the optical fiber (35) is diffracted in a +1-th and/or -1-th order and headed for the photodiode part (33).
6. The bidirectional signal transmission device using light of claim 5, wherein the polarization diffraction element (34, 134, 36, 136) is a refractivity change diffraction element obtained by forming a proton exchange region and a dielectric film on the position of the diffraction pattern of a plate made of a birefringence material.
7. The bidirectional signal transmission device using light of claim 5 or 6, wherein the optic axis of the polarization diffraction element (34, 134, 36, 136) is approximately perpendicular to the direction of linear polarization of light emitted from a VCSEL part that faces the polarization diffraction element.
8. The bidirectional signal transmission device using light of claim 1, wherein the optical unit further comprises a lens (238, 239) installed between a VCSEL part (31, 37) and a diffraction element (34, 134, 36, 136) or between the diffraction element (34, 134, 36, 136) and the input/output port (35a, 35b) of an optical fiber, for coupling light from a VCSEL part to the optical fiber (35).
9. The bidirectional signal transmission device using light of claim 1, wherein the optical unit is single-modularized, so that it is electrically separated/connected from/to the first and second apparatuses.
10. The bidirectional signal transmission device using light of claim 9, wherein the optical unit and at least some components of the first and second circuit units are single modularized.
11. The bidirectional signal transmission device using light of claim 1, wherein each of the first and second circuit units comprises:
  - a driver (25, 45) for driving a VCSEL part; and
  - an amplifier (27, 47) for amplifying a current signal output from the photodiode part.
12. The bidirectional signal transmission device using light of claim 11, wherein each of the first and second circuit units further comprises a controller (21, 41) installed between an apparatus and the amplifier (27, 47) and the driver (25, 45), for converting an electrical signal from the apparatus into a signal that is suitable for controlling the driver, and converting a signal from the amplifier into a signal suitable for the apparatus.
13. The bidirectional signal transmission device using light of claim 12, wherein the controller comprises:
  - an encoder (123) for encoding an electrical signal from an apparatus into an appropriate signal;
  - a driver control core (125) for converting the encoded signal into a signal that is suitable for controlling the driver, and applying the converted signal to the driver; and
  - a decoder (127) for decoding a signal from the amplifier into a signal that is suitable for the apparatus.
14. The bidirectional signal transmission device using light of claim 13, wherein the controller further comprises a multiplexer (129) between the encoder and the driver control core.
15. The bidirectional signal transmission device using light of claim 12, wherein the first and/or second circuit unit further comprises a switch installed between the controller and the driver and amplifier, for selectively switching on and off the driver and/or the amplifier.

FIG.1 (PRIOR ART)

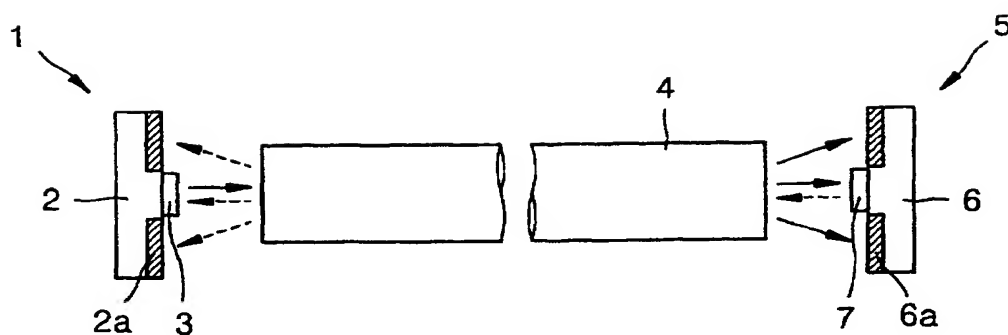


FIG.2

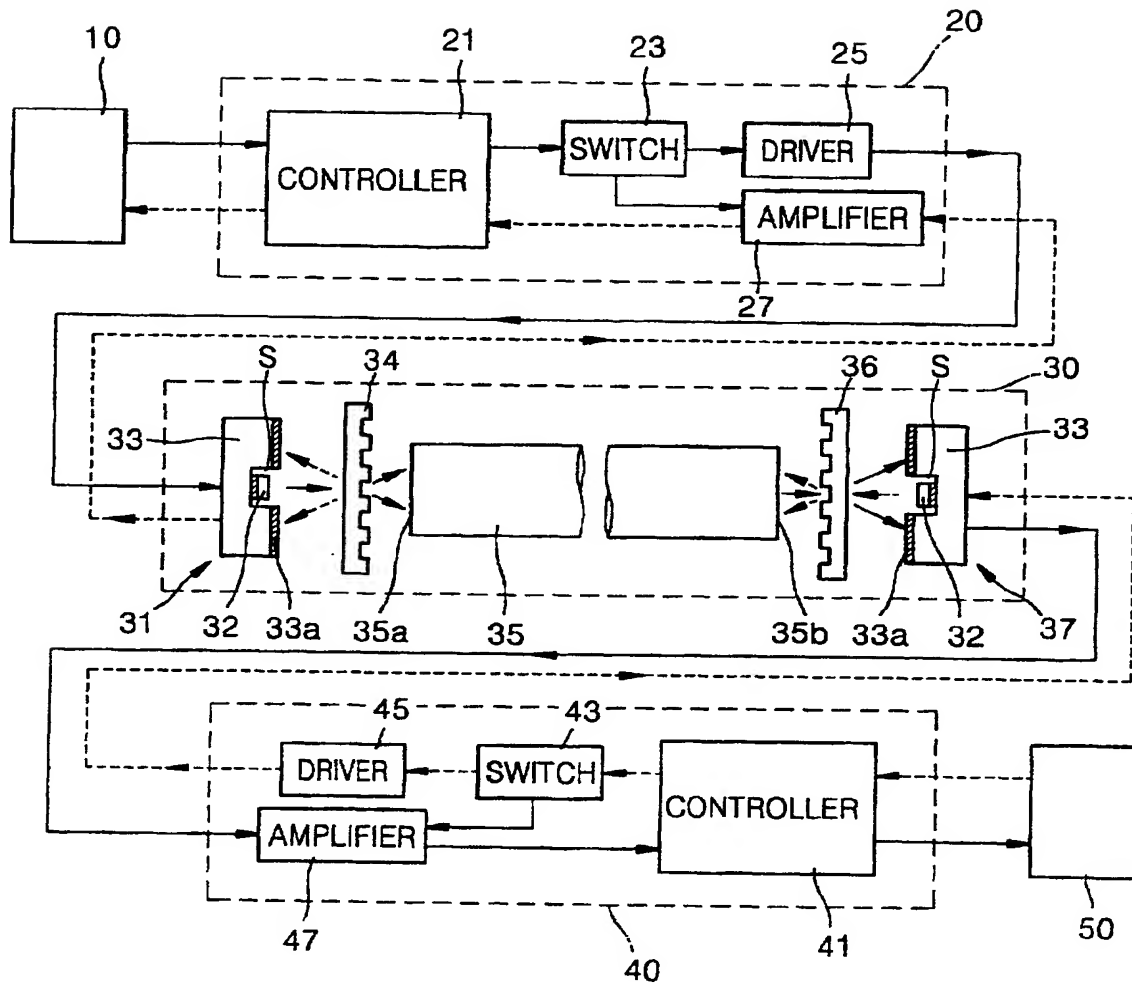


FIG.3

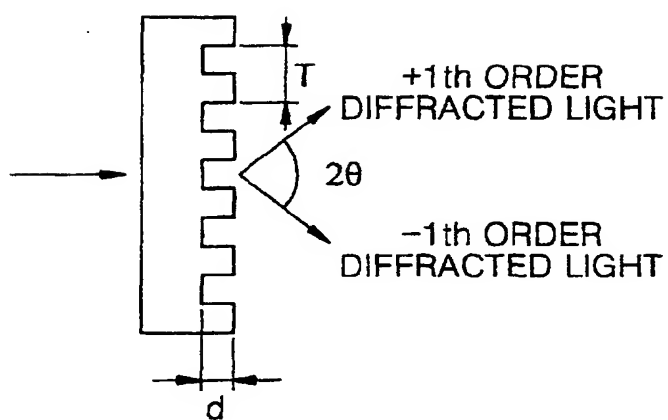


FIG.4

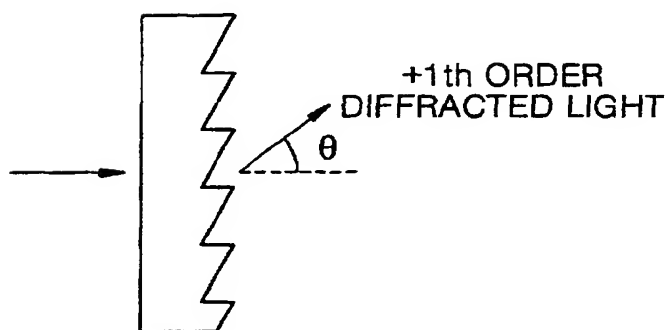


FIG. 5

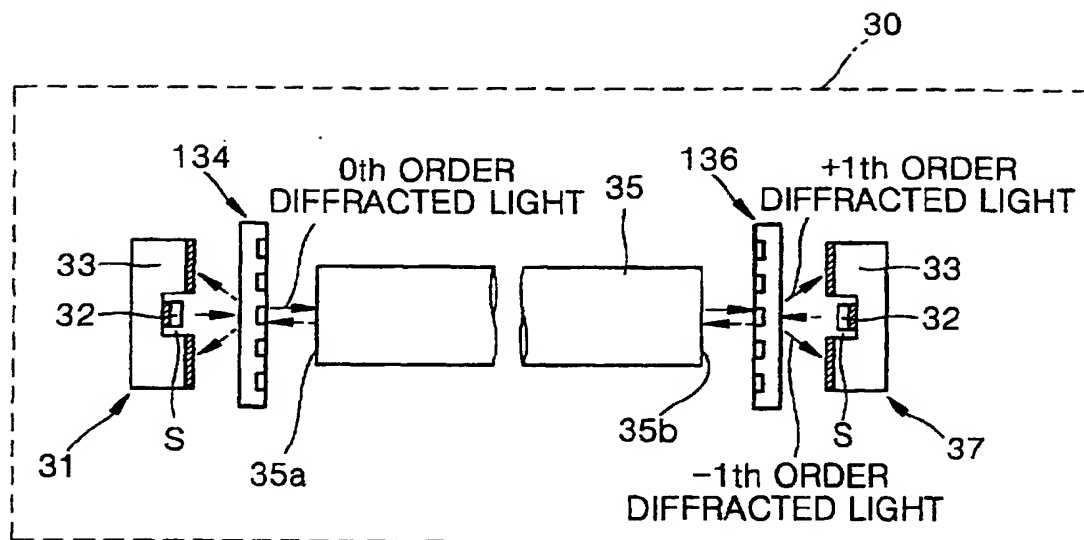


FIG. 6

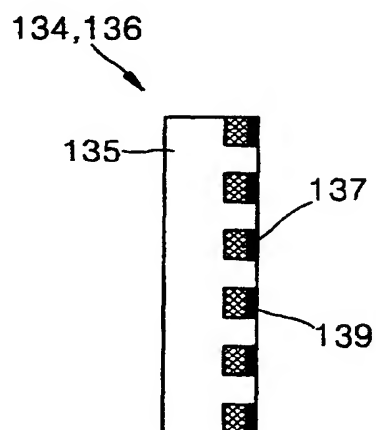


FIG. 7

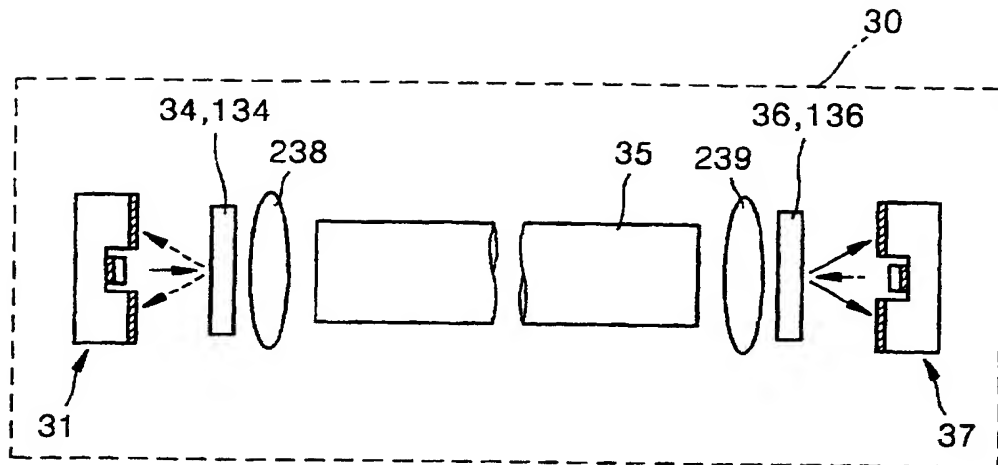


FIG. 8

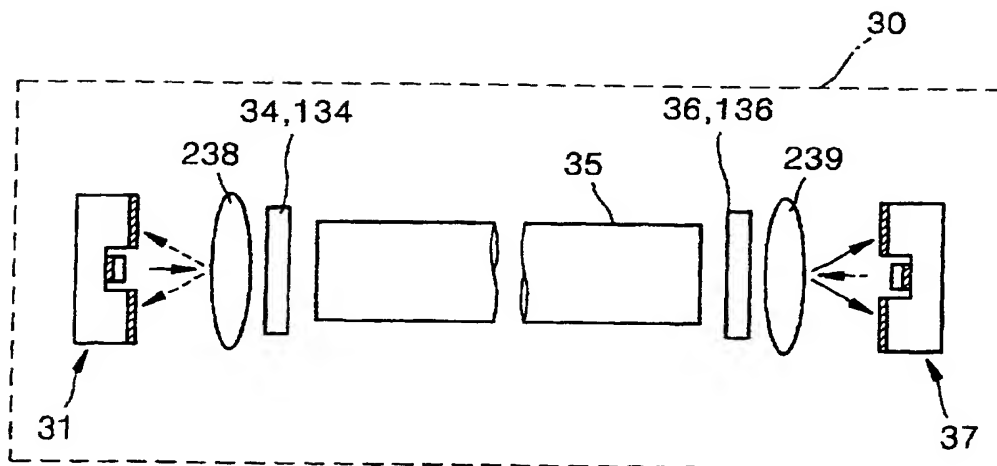


FIG. 9

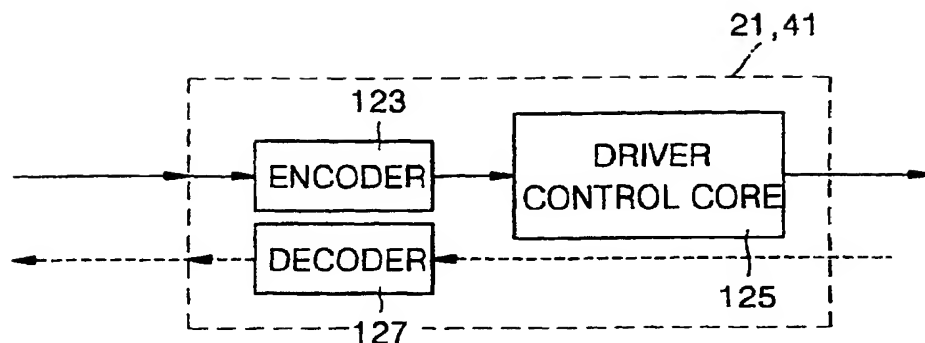


FIG. 10

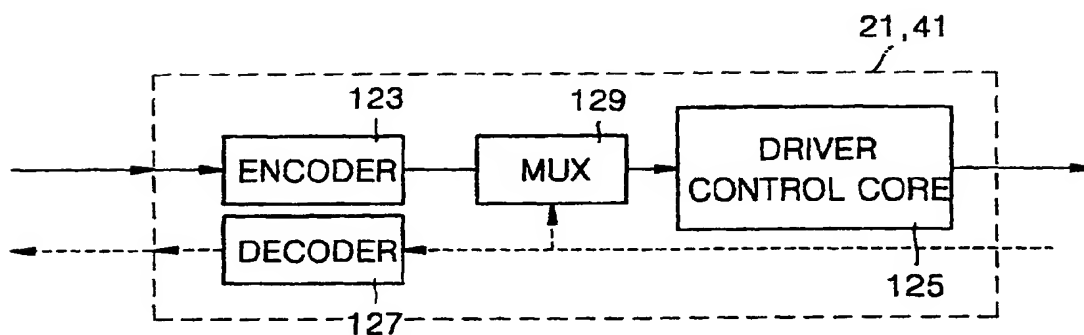
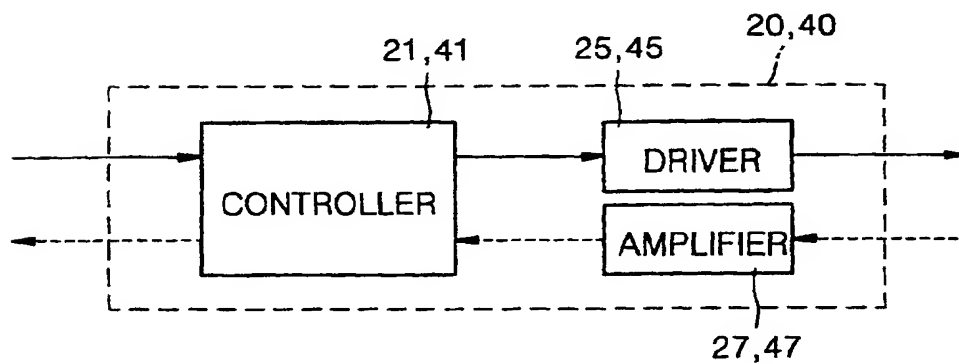
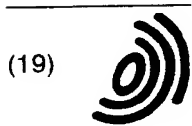


FIG. 11





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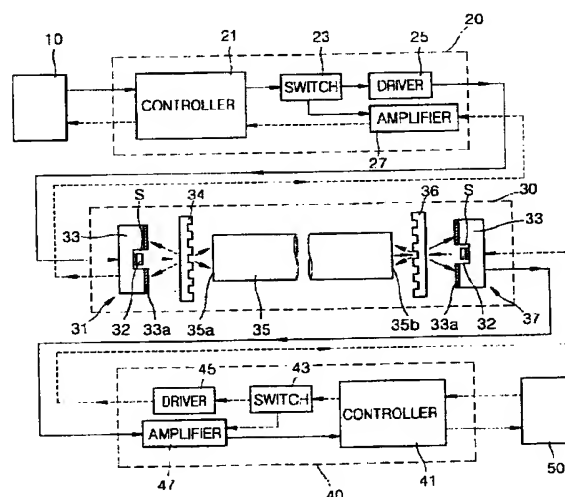
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### (54) Bidirectional signal transmission device using light

(57) A bidirectional signal transmission device using light which adopts a photodiode-incorporated vertical cavity surface emitting laser (VCSEL) as light devices so that signal transmission and reception between facing light devices is achieved via the same channel, is provided. This bidirectional signal transmission device using light includes an optical unit (30), a first circuit unit for controlling a first light device (31), and a second circuit unit for controlling a second light device (37). The optical unit includes first and second light devices (31, 37) having a VCSEL part and a photodiode part incorporated with the VCSEL part, at least one optical fiber (35) installed between the first and second light devices (31, 37), and diffraction elements (34, 36) installed between the first light device (31) and the input port (35a) of the optical fiber and between the second light device (37) and the output port (35b) of the optical fiber (35), respectively, for selectively diffracting incident light so that light output from the optical fiber is received by the photodiode part. In this bidirectional signal transmission device using light, light emitted from an optical fiber is diffracted in an +1-th and/or -1-th order by diffraction elements, and heads for the photodiode part of the light devices, so that a received signal having a high S/N ratio can be detected. Also, the bidirectional signal transmission device using light adopts a photodiode-incorporated VCSEL manufactured as a single body in a semiconductor manufacturing process, so that a die-bonding process can be omitted.

FIG.2



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# EUROPEAN SEARCH REPORT

Application Number  
EP 01 30 1652

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 555 334 A (OHNISHI ET AL) 10 September 1996 (1996-09-10) * abstract * * column 1, line 41 - column 3, line 64 * * column 4, line 59 - column 6, line 63 * * column 12, line 6 - column 14, line 51 * * figures 1-3,10,12,13 *	1-4,8-15	H04B10/24 G02B6/42 H01S5/026 H01S5/183
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X	EP 0 323 602 A (PENCOM INTERNATIONAL CORPORATION) 12 July 1989 (1989-07-12) * the whole document *	1-4,8-15	
A	-----	5-7	
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X	US 4 730 330 A (PLIHAL ET AL) 8 March 1988 (1988-03-08) * abstract * * column 1, lines 30-63 * * column 4, line 46 - column 6, line 66 * * figures 1,1A *	1-4,8-15	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04B G02B H01S
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1 The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 22 March 2005	Examiner Rolan Cisneros, E
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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